International Journal of Renewable and Sustainable Energy
2014; 3(5): 108-114
Published online September 20, 2014 (http://www.sciencepublishinggroup.com/j/ijrse)
doi: 10.11648/j.ijrse.20140305.14
ISSN: 2326-9715 (Print); ISSN: 2326-9723 (Online)

Assessment of global solar radiation absorbed in Maiduguri, Nigeria

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To cite this article:
Medugu Dale Waida. Assessment of Global Solar Radiation Absorbed in Maiduguri, Nigeria. *International Journal of Renewable and Sustainable Energy.* Vol. 3, No. 5, 2014, pp. 108-114. doi: 10.11648/j.ijrse.20140305.14

Abstract: Assessment of Global Solar Radiation Absorbed in Maiduguri, Nigeria was carried out in order to assist researchers in the field of solar radiation especially in developing countries that are increasingly faced with a serious data constraint. This will prove useful to many fields of study that rely on atmospheric energy input. The irradiation data was measured with the aid of constructed solar cell-based Pyranometer called the Reliable Model Pyranometer (RMP 002) at promising site. Insolation data at 1 min intervals were recorded for Maiduguri, Nigeria, using data loggers. The data were stored in a propriety binary format and later saved as text files that were imported into excel. From the data obtained, it was observed that maximum values of insolation occurred during the winter period while the minimum occurred during the summer period.

Keywords: Global Solar Radiation, Irradiation Data, Pyranometer, Data Loggers, Insolation

1. Introduction

Solar radiation is radiant energy emitted by the sun from a nuclear fusion reaction that creates electromagnetic energy. It is the dominant, direct energy input into the terrestrial ecosystem; and it affects all physical, chemical, and biological processes. It is the World's most abundant and permanent energy source. The amount of solar energy received by the surface of the earth per minute is greater than the energy utilization by the entire population in one year. The sun is the driving force for all atmospheric processes. It provides a natural influence on the earth's atmosphere and climate [1]

Solar radiant intensity is the expression of that input of energy upon the planet. Therefore, the ability to understand and quantify its value and distribution accurately is important in the initial understanding and modeling of any other thermodynamic or dynamic process in the earth-ocean-atmosphere system. The design of many technical instruments such as coolers, heaters, and solar energy electricity generators in the form of photovoltaic cells, requires terrestrial irradiation data at the study area. Scientific and technological studies in the last three decades tried to convert the continuity of solar energy into sustainability for the human comfort. Accurate estimations of global solar radiation need meteorological, geographic, and astronomical data and especially, many estimation models are based on the easily measurable sunshine duration at a set of meteorology stations. Such models include that of [2] – [12] to mention but a few.

Unfortunately, however, too little is known about the distribution of incoming solar radiation. A more complete and precise description of that distribution will prove useful to many fields of study that rely on atmospheric energy input, such as agricultural planning [13], architectural design [14], and engineering [15]. For these reasons, measurements of solar radiation distribution and its analysis is important and relevant.

The best way of knowing the amount of global solar radiation at a site is to install pyranometers at different locations in the given region. In the present work, solar radiation measurement has been done for Maiduguri with the aid of a constructed Reliable Model Pyranometer (RMP 002) in order to utilize solar energy for useful purpose.

2. Materials and Methods

The Reliable Model Pyranometer (RMP 002) constructed is a solar cell – based type. Construction of solar cell – based pyranometers are conceptually very simple and cheap. However, they require care design based on an understanding of the underlying physical principles.

RMP 002 generates an electrical signal proportional to the irradiance received and converts the small current received from the detector to a voltage and amplifies it to a voltmeter. It was then calibrated against a reference high quality pyranometer, CMP 3 whose calibration was trusted (14.71±0.36 μV/W/m^2) obtaining a calibration constant of $4550 \pm 0.03 Wm^{-2}$ [16], following the ISO 9847 standard. The purpose of this calibration is to eliminate or reduce bias in the user's measurement system relative to the reference base.

Measurement of solar radiation for a location in Maiduguri, Borno State of Nigeria, was obtain with the aid of the RMP 002 for a period of twelve months from November 3, 2008 through November 6, 2009. Data at 1 min intervals was also recorded using a HOBO data logger and are displayed in Figures 1 to 13. The logger has a USB interface with proprietary software for communicating with a computer. The data was stored in a propriety binary format and later saved as a text file that was imported into excel.

3. Results and Discussion

The instruments used for this project is a constructed reliable model pyranometer (RMP 002). The HOBO data loggers in the unit of Wm^{-2} display the amounts of solar radiation falling on the pyranometer. The pyranometer was placed in a secured place which is not blocked by local landscape features, such as trees, buildings, hills or mountains that may otherwise shade the instrument during different times of the day. The choice of locations was based on the requirements that for the optimum amount of global radiation to be received, the field of view of the pyranometer' sensor must be free from obstructions at all times.

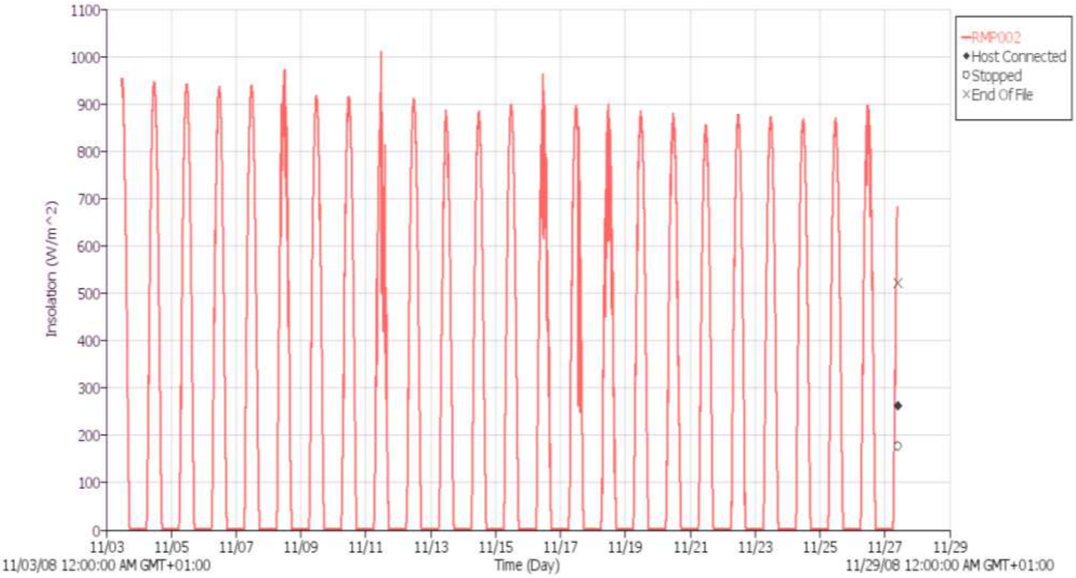

Figure 1. *Insolation recorded during the period from November 3 through November 27, 2008.*

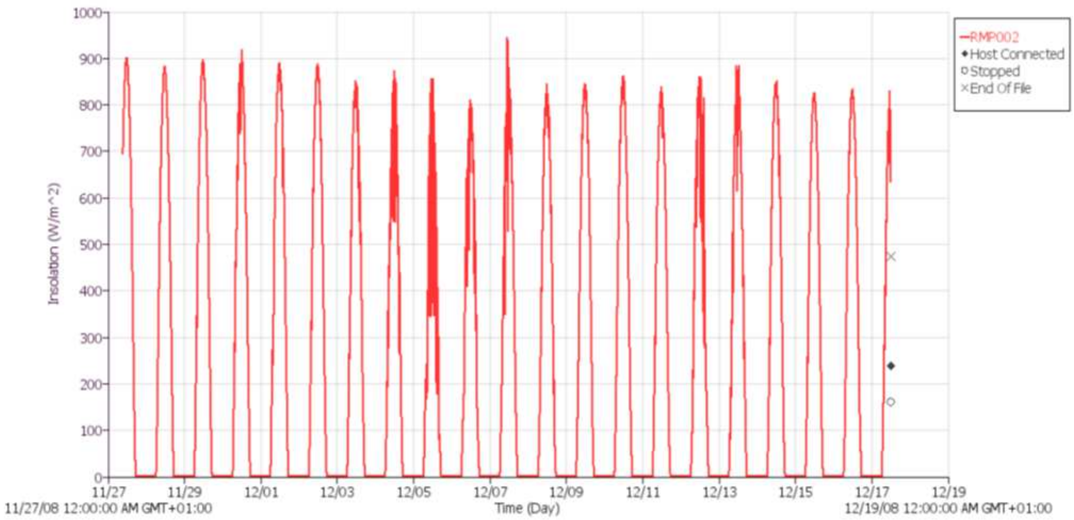

Figure 2. *Insolation recorded during the period from November 27 through December 17, 2008.*

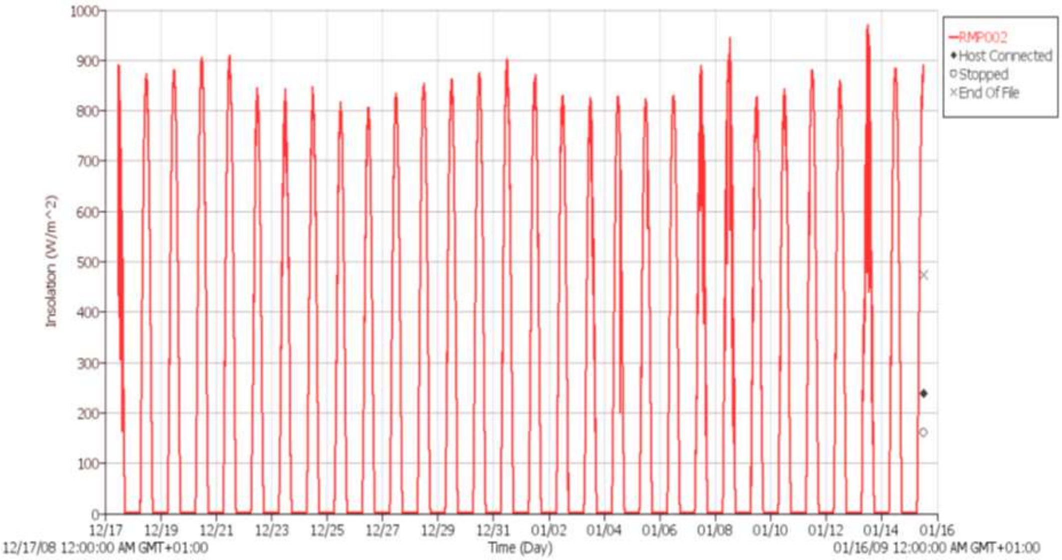

Figure 3. *Insolation recorded during the period from 17th December, 2008 through 15th January, 2009.*

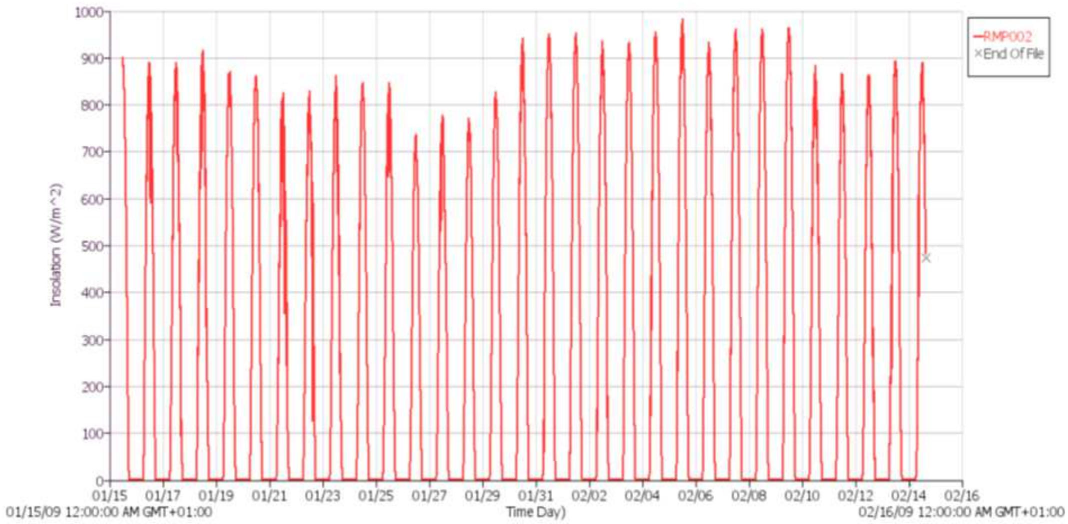

Figure 4. *Insolation recorded during the period from January 15 through February 14, 2009.*

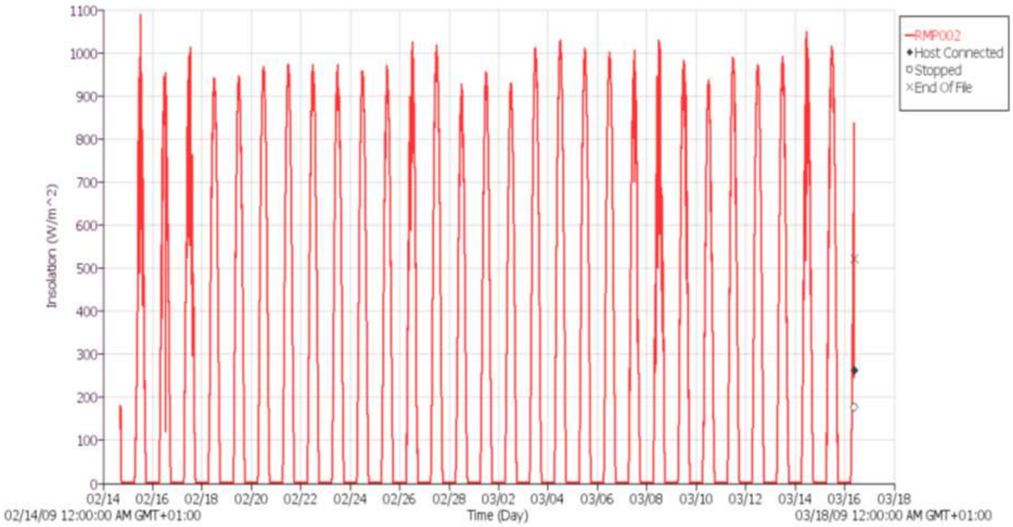

Figure 5. *Insolation recorded during the period from February 14 through March 16, 2009.*

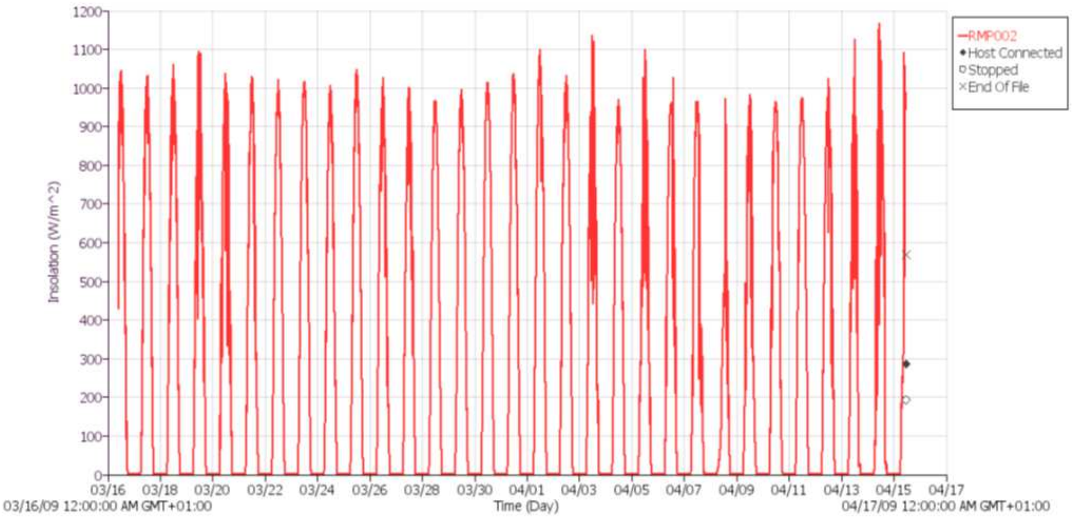

Figure 6. *Insolation recorded during the period from March 16 through April 15, 2009.*

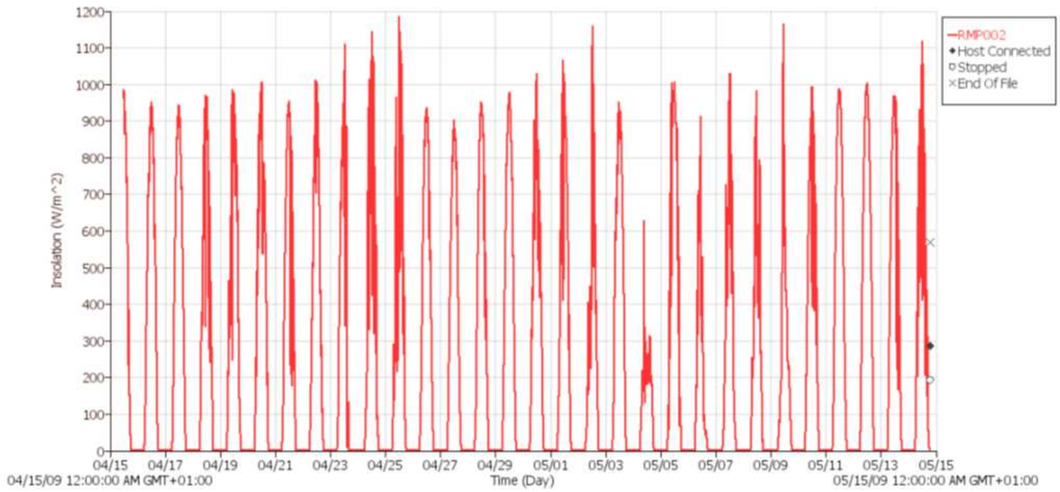

Figure 7. *Insolation recorded during the period from April 15 through May 14, 2009.*

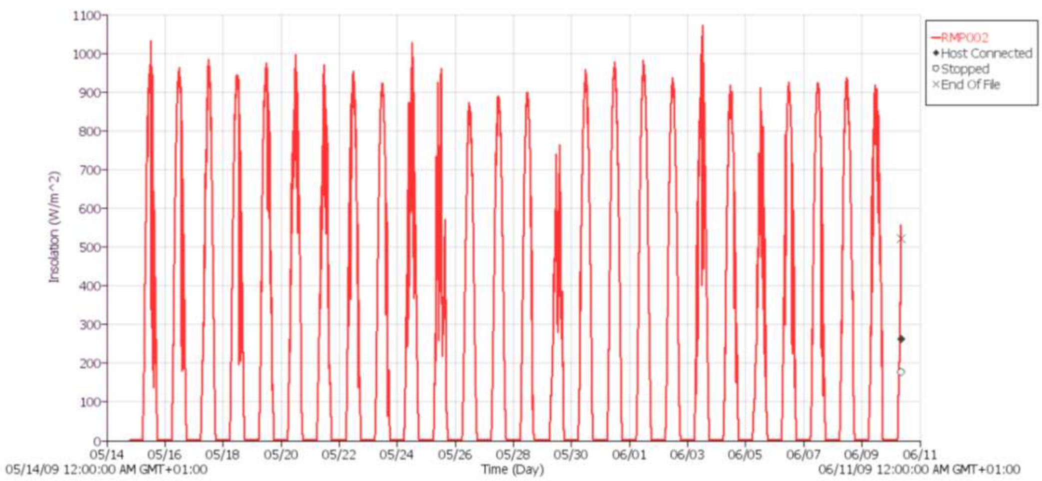

Figure 8. *Insolation recorded during the period from May 15 through June 10, 2009.*

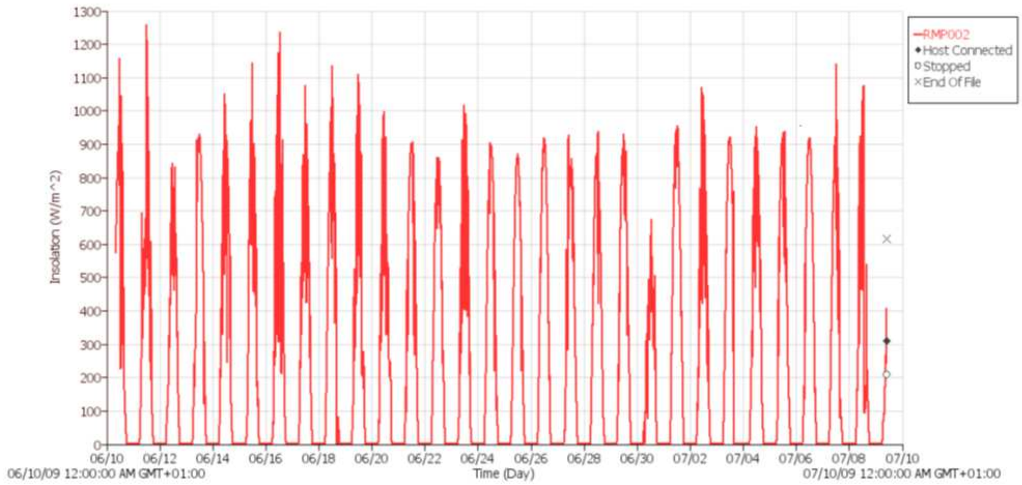

Figure 9. *Insolation recorded during the period from June 10 through July 9, 2009.*

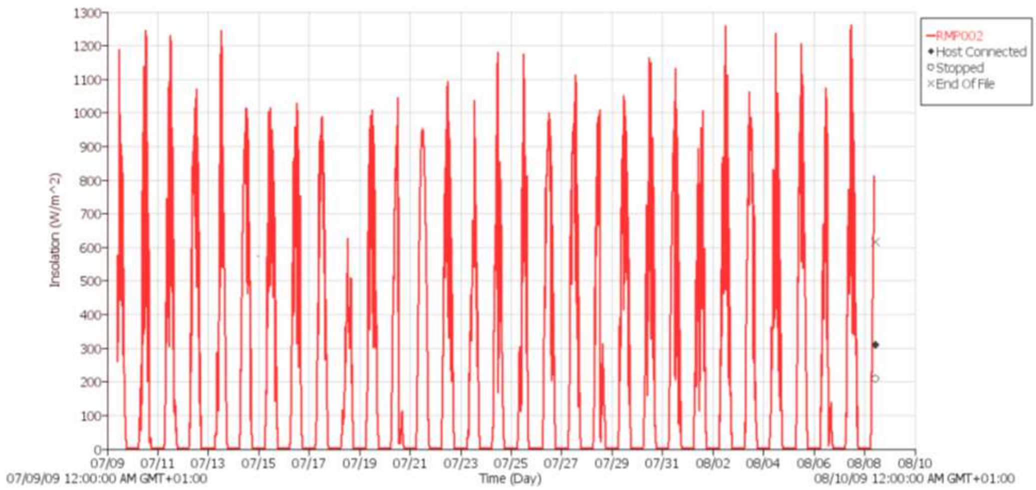

Figure 10. *Insolation recorded during the period from July 9 through August 8, 2009.*

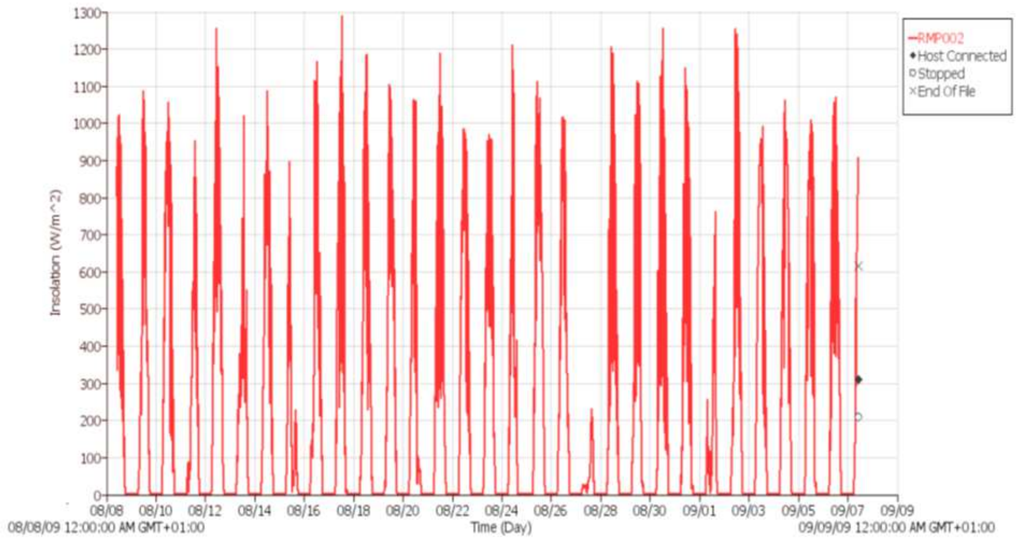

Figure 11. *Insolation recorded during the period from August 8 through September 7, 2009.*

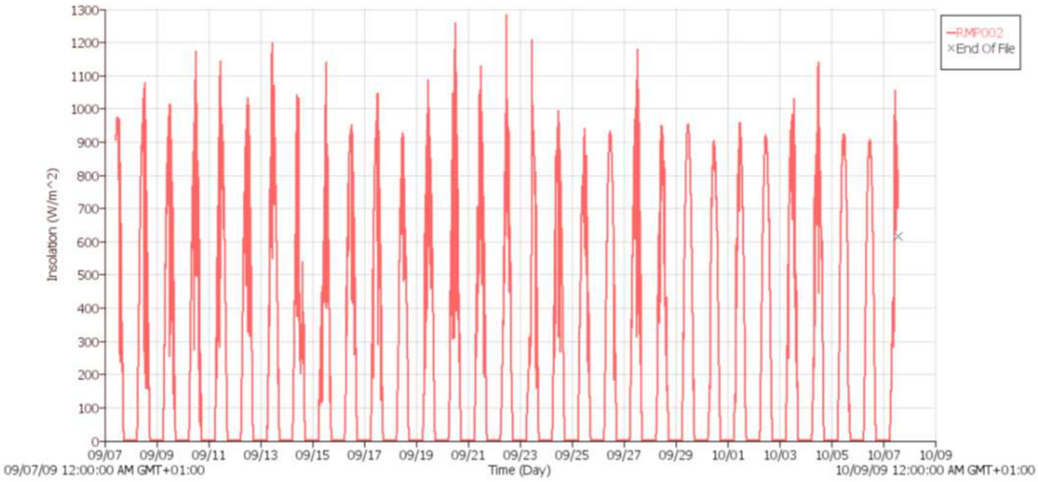

Figure 12. *Insolation recorded during the period from September 7 through October 7, 2009.*

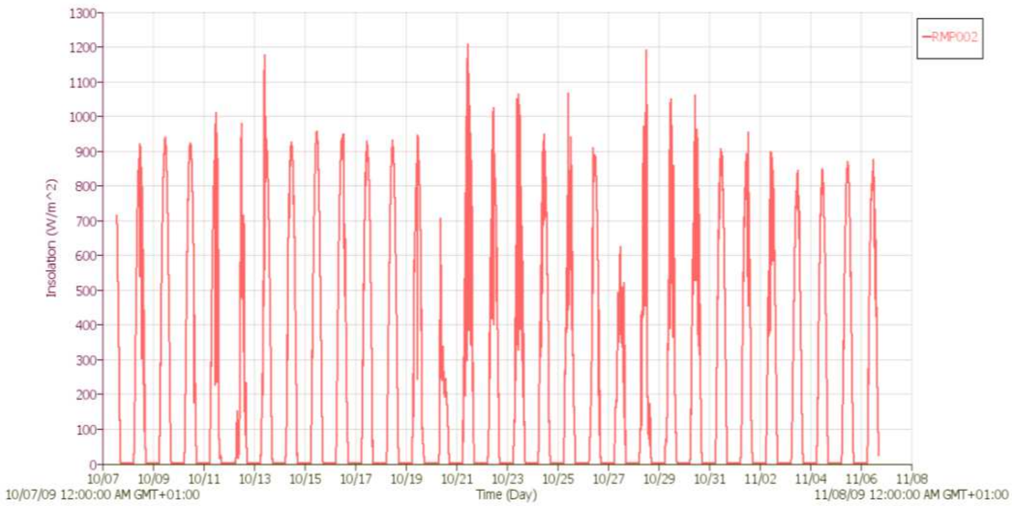

Figure 13. *Insolation recorded during the period from October 7 through November 6, 2009.*

In November 2008, measurements for solar radiation in Maiduguri were recorded and the results are shown in Figures 1 and 2. The measurements fell within the cool dry (harmattan) season. They were no rainfall recorded throughout the month and most of the days are cloud free days except 8^{th},11^{th}, 16^{th},17^{th}, 18^{th}, 26^{th} and 30^{th} were partially cloudy. Insolations vary from 825.74 Wm^{-2} (on 21^{st}) to 964.57 Wm^{-2} (on 16^{th}).

The measured amount of irradiation for December 2008 is depicted in Figures 2 and 3 demonstrates clear days behavior with exception of 3^{rd}, 4^{th}, 5^{th}, 6^{th}, 7^{th}, 8^{th}, 12^{th}, 13^{th} and 17^{th} which are partially cloudy. There was no rainfall recorded but particulate matters from harmattan were observed. The maximum and minimum insolations occurred on 21^{st} and 6^{th} with values of 885.20 Wm^{-2} and 797.39 Wm^{-2} respectively.

The measurements of global solar radiation were made in the month of January 2009 and the results are shown in Figures 3 and 4. The result reveals that there were low altitude clouds were in the sky corresponding to 4^{th}, 7^{th}, 8^{th}, 13^{th}, 16^{th}, 17^{th}, 18^{th}, 21^{st}. 22^{nd}, 23^{rd}, 25^{th}, 27^{th} and 30^{th}. The maximum insolation of 958.85 Wm^{-2} was recorded on 13^{th} while the minimum insolation of 726.61 Wm^{-2} was recorded on 26^{th}.

Out of the measurements recorded for the month of February 2009 (Figures 4 and 5), 10^{th}, 15^{th}, 16^{th}, 17^{th} and 26th were partially cloudy. The maximum and minimum insolation was 984.38 Wm^{-2} (on 27^{th}) and 845.56 Wm^{-2} (on 12^{th}) respectively.

The amount of solar radiation for March 2009 indicates the presence of clouds on 7^{th}, 8^{th}, 9^{th}, 14^{th}, 16^{th}, 17^{th}, 18^{th}, 19^{th}, 20^{th}, 21^{st}, 26^{th} and 27^{th} (Figures 5 and 6). The maximum and minimum irradiation of 1038.17 Wm^{-2} and 922.05 Wm^{-2} are corresponding to 20^{th} and 2^{nd} days, respectively.

The measurements of solar radiation were recorded in the month of April 2009 and the results are depicted in Figures 6 and 7. The sky was relatively clear on the 11^{th}, 16^{th}, 17^{th}, 26^{th}, 27^{th}, 28^{th} and 29^{th}. However, the amount of maximum and minimum solar radiation was 1100.50 Wm^{-2} (on 3^{rd}) and 822.91 Wm^{-2} (on 8^{th}) respectively.

The solar irradiance for May 2009 ranges from a minimum of 284.68 Wm^{-2} to a maximum of 1015.52 Wm^{-2} as shown in Figures 7 and 8. The sky was clear throughout except on 11^{th}, 12^{th}, 26^{th}, 27^{th}, 28^{th}, 30^{th} and 31^{st}.

The result of the measurement of solar radiation conducted in the month of June 2009 is shown in Figures 8 and 9. The sky was only clear on 1^{st}, 2^{nd}, 8^{th} and 26^{th}. The maximum amount of solar radiation (970.22 Wm^{-2}) on 23^{rd} and minimum amount (599.12 Wm^{-2}) on 30^{th} were recorded.

The irradiations recorded in July 2009 (Figures 9 and 10) demonstrate the presence of thick clouds in the sky that blocks the sun except on 4^{th}, 6^{th} and 21^{st}. Since this month marked the rainfall, the temporal increased in insolations due to reflection of radiations were also noted throughout. The highest insolation of 1055.20 Wm^{-2} on 13^{th} and the lowest insolation of 488.66 Wm^{-2} were seen.

The month of August 2009 marked the peak of rainfall. The amount of solar radiation due to the presence of thick dark grey clouds reducing the intensity of solar radiation are presented in Figures 10 and 11. The phenomenon by which sunlight reflected from the sides of clouds temporarily increased the amount of insolation reaching the surface over what was seen under a clear sky was noted. The maximum and minimum irradiance of 1077.85 Wm^{-2} and 222.35 Wm^{-2} took place on 17^{th} and 27^{th} respectively.

The solar irradiance for September 2009 ranges from a minimum of 426.33 Wm^{-2} to a maximum of 1069.35 Wm^{-2} as shown in Figures 11 and 12. Only 29^{th} and 30^{th} were clear days while the sun was partially blocked by grayish cloud throughout the remaining days.

Measurements results of solar irradiance for the month of October 2009 are depicted in Figures 12 and 13. Less than 50% of the days (3^{rd}, 4^{th}, 7^{th}, 8^{th}, 11^{th}, 12^{th}, 13^{th}, 19^{th} and 21^{st} to 30^{th}) were clear while the rest were accomplished by partial clouds. The maximum radiation of 1111.82 Wm^{-2} was on 4^{th} and the minimum of 417.84 Wm^{-2} on 27^{th}.

4. Conclusion

Assessment of Global Solar Radiation Absorbed in Maiduguri, Nigeria has been carried out. This is to assist researchers in the field of solar radiation in developing countries that are increasingly faced with a serious data constraint for the feasibility of possible and efficient utilization of solar energy due to availability of sufficient and functional instruments for measuring solar radiation because of their high importation costs and maintenance. To resolve this data constrain, Reliable Model Pyranometer was designed and constructed. Considering the overall result for Maiduguri, the maximum global solar radiation occurred in the month of March 2009. August 2009 and October 2009. The maximum values occurred during the winter period while the minimum occurred during the summer period. The Reliable Model Pyranometer can then be used in any installation where reliable measurement of solar irradiance is necessary, especially in those where cost may be a deciding factor in the choice of a meter.

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